2p2h effects on the weak pion production cross section

A. Mariano[†] and C. Barbero[†]

[†]Departamento de Física, Facultad de Ciencias Exactas, Universidad Nacional de La Plata - IFLP (Conicet), C.C. 67, La Plata, Argentina

Abstract

The $\nu_l n \to l^- p$ QE reaction on the A-target is used as a signal event or/and to reconstruct the neutrino energy, using two-body kinematics. Competition of another processes could lead to misidentification of the arriving neutrinos, being important the fake events coming from the CC1π background. A precise knowledge of cross sections is a prerequisite in order to make simulations in event generators to substract the fake ones from the QE countings, and in this contribution we analyze the different nuclear effects on the CC1π channel. Our calculations also can be extended for the NC case.

$\nu_\mu \to \nu_x$ disappearance experiments uses $\nu_\mu n \to \mu^- p$ CCQE to detect neutrinos and reconstruct its energy. E_ν determination could be wrong for a fraction of CC1π^+ background events (20%) $\nu_\mu p \to \mu^- p\pi^+$, that can mimic a CCQE one if the pion is absorbed and/or not detected. These processes take place into the target nucleus and nuclear effects as smearing (S) of the reconstructed energy by the momentum distribution (n_A) of the target binding (B) nucleons, should be taken into account. In addition final state interactions (FSI) of the emerging hadrons generate energy lost,change of direction,charge transfer or multiple nucleon knock out(np-nh). Finally meson exchange currents (MEC) processes lead to additional contributions to one-body current generated. In what follows we concentrate on the 2p2h+1π contributions to the pion production cross section, and compare with the 1p1h+1π one already analyzed previously [1]. The 2p2h+1π amplitude is
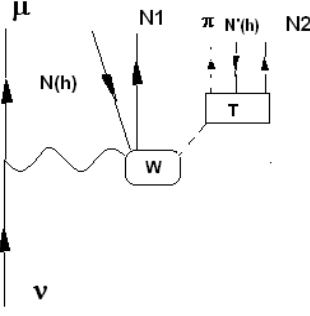
1

Figure 1: Amplitude for the $\nu N \to l N' N_1 N_2 \pi$ ($2p2h + 1\pi$) process.

depicted in Figure 1 and the corresponding differential cross section reads ($\mathcal{N}^2(\boldsymbol{k}) \equiv \frac{f}{(2\pi)^3 E(\boldsymbol{k})}$, $f = 1/2(M)$ for bosons(fermions))

$$d\sigma_{\nu A}^{2p2h+1\pi} = \frac{n_A(\boldsymbol{N})(1 - n_A(\boldsymbol{N_1}))}{|\mathbf{v}_\nu - \mathbf{v}_A| 2E(\boldsymbol{\nu})} \frac{1}{2} \sum_{m_\nu, m_N, m_l, m_{N_1}} \int \frac{d^4 \pi'}{(2\pi)^4}$$

$$\times \left[\mathcal{S} \sum_{m_{N_2} m'_N} |T(N_2 m_{N_2}, \pi, N' m_{N'}, \pi')|^2 \frac{n_A(\boldsymbol{N'})(1 - n_A(\boldsymbol{N_2}))}{(\pi'^2 - M_\pi^2)^2} \right.$$

$$\times (2\pi)^4 \delta^4(N_2 + \pi - \pi' - N') d^3 N_2 \mathcal{N}^2(\boldsymbol{N_2}) d^3 N' \mathcal{N}(\boldsymbol{N'}) d^3 \pi \mathcal{N}^2(\boldsymbol{\pi}) \Big]$$

$$\times |W^\mu(N_1 m_{N_1}, l m_l, \pi', N m_N, \nu m_\nu) J^l_\mu(l m_l, \nu m_\nu)|^2$$

$$\times (2\pi)^4 \delta^4(N_1 + \pi' + l - \nu - N) \, d^3 l \mathcal{N}^2(\boldsymbol{l}) \, d^3 N_1 \mathcal{N}^2(\boldsymbol{N_1}) d^3 N \mathcal{N}(\boldsymbol{N}),$$

being $N, \pi, l, \nu \equiv (E(\boldsymbol{N}, \boldsymbol{\pi}, \boldsymbol{l}, \boldsymbol{\nu}), \, \boldsymbol{N}, \boldsymbol{\pi}, \boldsymbol{l}, \boldsymbol{\nu})$, $E(\boldsymbol{k}) = \sqrt{\boldsymbol{k}^2 + M^2}$, $m \equiv$ spin, $\mathcal{S}$ symmetrization factor, T $\pi' N' \to \pi N_2$ rescattering is simplified replacing

$$[\cdots] \Rightarrow \frac{1}{(\pi'^2 - M_\pi^2 - \Pi(\pi'))} \Rightarrow 2\pi \delta(\pi'^2 - M_\pi^2 - \Re(\Pi(\pi'))),$$
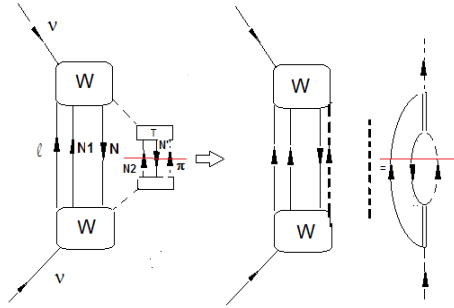
as shown in Figure 2.

Figure 2: Simplification to calculate $\pi' N'(h)$ rescattering.

Figure 3 shows results for the total CC1π^+ cross section and the gradual effect of the B, S and FSI within the 1p1h+1π configuration space. Also the results for B+S+FSI in the 2p2h+1π one and full 1p1h+2p2h+1π one are shown. They are also shown for the differential cross section in Figure 4.B effects are

2

considered within the Relativistic Hartree approximation (RHA) of QHD I [2], for N and Δ using universal couplings. n_A is obtained from a perturbative approach in nuclear matter within a 2p2h+4p4h configuration space[3]. FSI on nucleons is taken (Toy model !) through the RHA effective fields also for final N, while for pions we use the Eikonal approach[4].
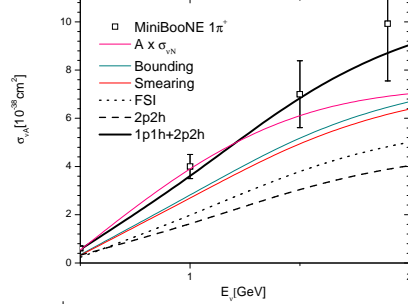

Figure 3: Total $1\pi^+$ cross section compared with MiniBooNE data (see[1]).
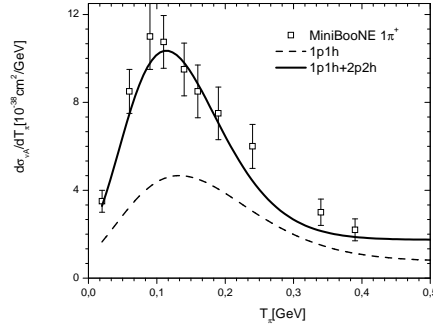

Figure 4: $1\pi^+$ production differential cross section.

We conclude that 2p2h contribution is important and comparable to the 1p1h one. In the π^0 channel results are not so good in reproducing the data and nonresonant contributions and charge exchange terms should be included in the rescattering amplitude. Finally, MEC should be included at the same time that 2p2h contributions in order to have a more real estimation.

References

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